Surface Flow Visualization on a Hovering Tiltrotor Blade

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Fluorescent mini-tufts were used to visualize the flow behavior on the upper surface of the blade of a full-scale, hovering XV-15 tiltrotor installed in the Ames 80- by 120-Foot Wind Tunnel. The objectives of the test were to determine whether the flow direction could be deduced from the tuft motion and whether this visualization technique could be practically implemented for forward flight. A dual camera/strobe system was used to acquire inboard and outboard images of approximately 2500 tufts on the upper surface of one blade. The tufts were approximately 0.625 inch in length; tuft diameters of 0.002 and 0.006 inch were used. Tuft images were acquired for a range of thrust conditions up to and including stall.

The first part of the figure shows three overlaid images for the inboard blade region of a stalled condition. There are several 0.002-inch-diameter tufts near the trailing edge that are pointing upstream. Since the centrifugal force causes the tufts to point toward the tip, aerodynamic forces must be responsible for the upstream-pointing tufts. Therefore, areas of the local flow are reversed. The second part of the figure shows overlaid images of the outboard blade region for the same condition. An area of highly localized flow disturbance is shown centered at approximately r/R = 0.895 (where R is the rotor tip radius and r is the radial station). One explanation for this disturbance is that the flow is separated. Another possibility is that the disturbance is caused by interaction with the tip vortex from the preceding blade. The formation of the tip vortex is evident in the two rows nearest the blade tip (note tufts near trailing edge pointing toward tip). Although tuft sizes were selected to minimize the effect of centrifugal force on the tufts, distinguishing between the effects of aerodynamic and centrifugal forces on the tufts was not always possible. Nevertheless, the tuft motion can provide useful information about the behavior of the flow on the upper surface of the blade.

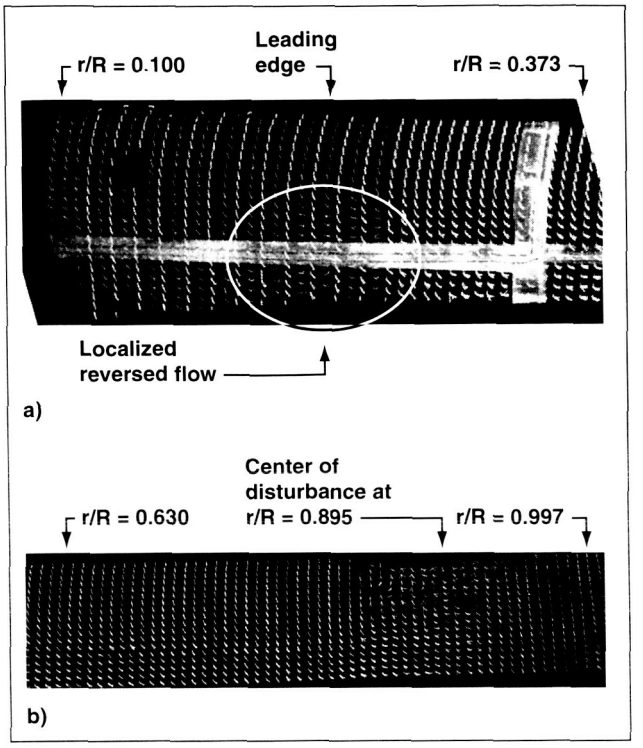

Fig. 1. Overlaid images of XV-15 upper blade surface tuft pattern: thrust coefficient = 0.0145; figure of merit = 0.702; tip Mach number = 0.56. (a) Inboard, (b) outboard.

This experimental setup was tailored for acquiring images in hover; however, images of similar quality are possible in forward flight, given some modification to the light source.

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